PAPERS ON CLIMATOLOGY IN RELATION TO AGRICULTURE, TRANSPORTATION, WATER RESOURCES, ETC.

THE CATCHMENT OF SNOWFALL BY MEANS OF LARGE SNOW BINS AND TOWERS.

By Prof. FRANK H. BIGELOW.

THE PROBLEM OF CATCHING THE SNOWFALL.

The catchment of the true amount of snow falling at any place, and the measurement of the equivalent amount of water has been a problem of great practical difficulty for meteorologists. In the case of rain there is no special trouble, because the force of gravitation upon the rain drops is sufficient to cause a comparatively rapid fall through the restraining atmosphere, so that the vertical component is much greater than the horizontal component of motion. A circular rim of about 8 inches in diameter therefore catches an average amount of rain, and the vertical depth is measured by a proper scale. In the case of snow, on account of the crystal nature of the mass and the exposure of large surfaces to the air, the vertical fall is relatively small. When the wind is blowing the horizontal motion often becomes more effective than the vertical fall, and snow is merely drifting about from place to place. The effect of the wind upon an 8-inch cylinder tube is to cause a series of complex stream lines around the opening, so that snow is blown about it in curves without entering the cylinder with any regularity. For this reason it has long been admitted that the ordinary Weather Bureau snow gage is ineffective as a snow catcher in itself, and the practise has been to cut out a cylinder of snow from an open place where the snow lies at an average depth, and convert this amount into the water equivalent. It has been sought to improve these cylindrical tubes by adding a wire hood of the Nipher pattern at the top, to modify the wind curves or lines of stream flow, and it is said that a gain of 25 per cent in accuracy has been attained. It is comparatively easy to arrive at a fair result regarding snow fall where intelligent observers are available, and personal attention can be given to each storm. With the growth of the interest in the use of water for irrigation and power purposes in the semiarid and arid regions of the Rocky Mountain Plateau, and adjacent districts, it has become very important to attempt to devise a method by which some knowledge of the snow conditions can be obtained at mountainous places where no observer lives, and where it is not possible to secure any record except by some automatic device, to be regulated by special visits made in the early autumn before snows fall and in the spring when they have ceased. A seasonal snow gage is a great necessity if it can be invented to work satisfactorily under such conditions. Accordingly the Weather Bureau undertook to make such a study of the subject under the supervision of Prof. Frank H. Bigelow, and this paper contains the first report on the progress that has been possible.

THE PLAIN AND LOUVERED SNOW BINS, THE 10-FOOT PLATFORM, THE 10-INCH STANDPIPE, THE WEATHER BUREAU 8-INCH RAIN GAGE, AND THE VERTICAL SCALES.

It seems important, before attacking the mechanical problems of the seasonal snow gage, to determine the form of the apparatus to be used in catching the snow that is to be conserved. Unless the normal amount of snow can be brought into and held within the apparatus it would not seem to be worth while to spend time and money on conserving an incorrect amount of snow supposed to represent the seasonal snowfall at the place. Accordingly, on the instructions issued by the Chief of the Weather Bureau through the Climatological Division, a number of stations were equipped in thirteen of the Western States with the apparatus that is necessary to test the several *principles* or *theories* that must be employed in constructing any form of snow apparatus. The several types of apparatus were placed side by side and the reports were gathered by the several section directors, independently of one another, so that any consensus of opinion attained would be entitled to weight. The apparatus consisted of five special pieces:

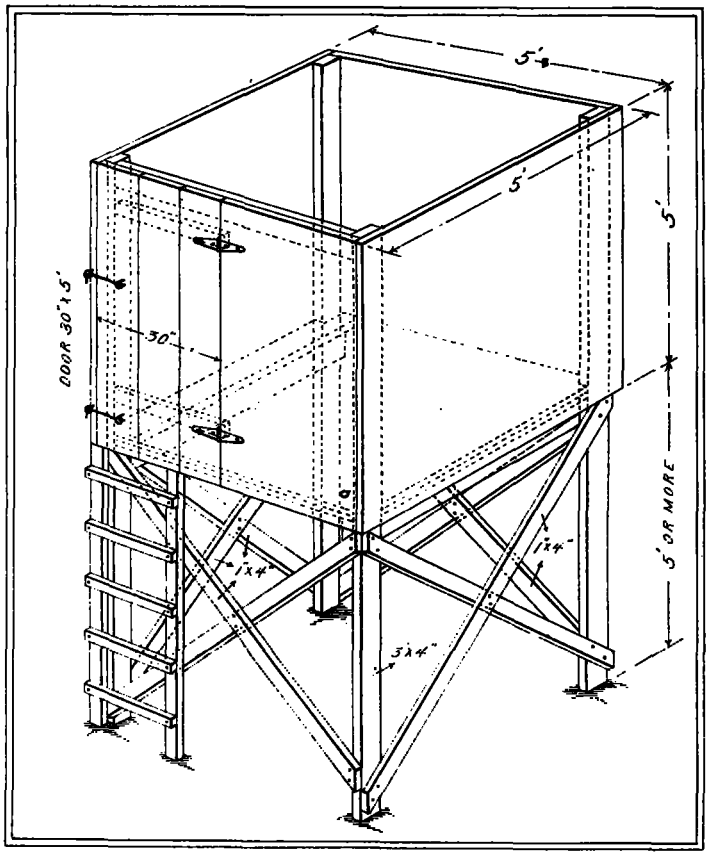

FIG. 1.—Snow bin.

Material—Selected pine or redwood, well dried.

12 pieces 16 feet by 10 inches by 1 inch.	2 6-inch strap hinges.
4 pieces 10 feet by 4 inches by 3 inches.	2 4-inch hooks.
4 pieces 16 feet by 6 inches by 1 inch.	100 feet ¼-inch wire rope.
3 pieces 10 feet by 3 inches by 2 inches.	4 pounds board wire nails.
3 pieces 12 feet by 2 inches by 1 inch.	1 pound 50d spikes.

Bins secured to trees or stakes by wire rope.
Double floor, top boards point toward hinged door.
All boards to be matched, tongued and grooved on edges.

1. A large snow bin, being a wooden box 5 feet on the side with the top open, and set on a stand 5 feet high, so that the upper edge is 10 feet above the ground. The bin is fitted with inside louvers, as shown on figs. 1, 2. In fig. 3 is given the specifications for the outside semicircular louver screens, by which an attempt was made to control the stream lines of the horizontal component at the edge of the bin. The theory of the bin is simply that of a very large opening to avoid the curves of air-flow around a small cylindrical pipe, and to give plenty of room for the snow to work into the opening by numerous paths; it is an elevated platform so protected by the sides of the bin that the snow can not blow away in high winds after the storm; the inside louvers break up the vortical eddies of the wind in the bin so that the snow falls nearly level on the floor; by elevating the bin to 10 feet above the ground it is evident that much of the surface drift of snow passes by the bin without affecting its contents, inasmuch as the surface drift is usually shallow; by covering in the lower 5 feet of the stand the snow bin becomes a *snow tower*, and the lower half can be devoted to a device for conserving the snow in the form of water.

2. A platform 10 feet square was laid on the ground near the bin. When the snow falls in a calm or in a light wind the platform catches a normal amount; in high winds snow is merely drifted upon or off the platform so that the amount lying upon it at any time is a product of the wind effect quite as much as of the snowfall itself. When snows become deep, unless the platform is raised from time to time and kept near the snow level, the drift makes it an impossible apparatus for accurate snow measures.

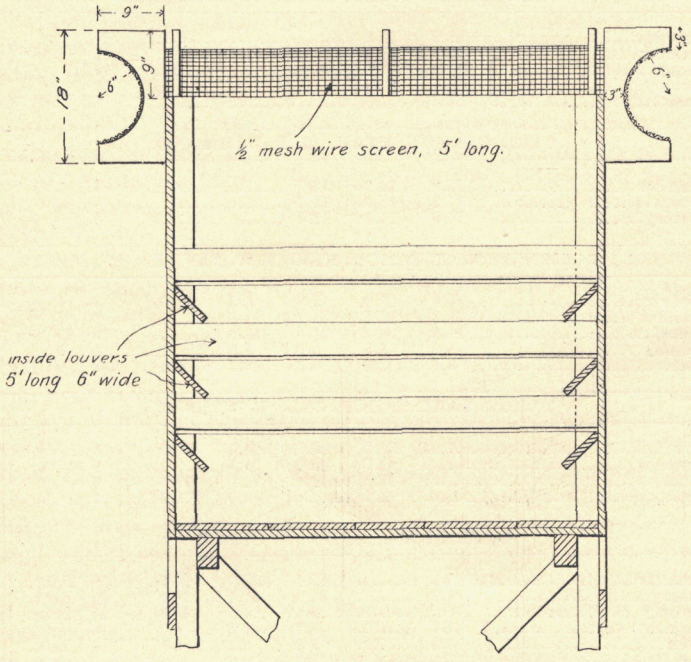

FIG. 2.—Snow bin.

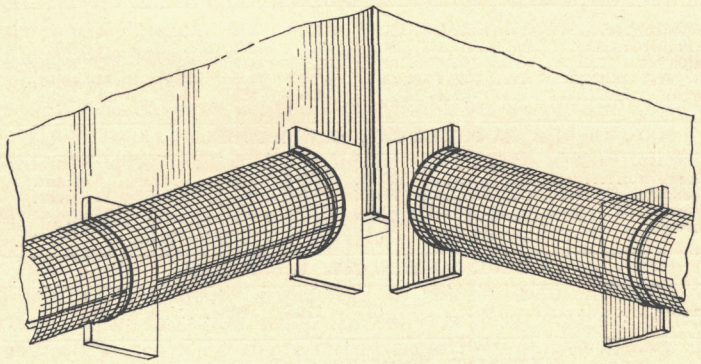

FIG. 3.—Drawing and description of inside louvers and outside semicircular screens to be added to snow bins.

Inside louvers.—Take boards 5 feet long and 6 inches wide and fasten them to the inside of the bin at an angle of 45°, sloping downward. Put three on each side, the top one being not nearer than 18 inches to the top of the bin and the lower one not nearer than 8 inches to the bottom. In order to avoid interfering at the corners they need not be placed at the same height on each side.

Outside semicircular screens.—Take a board 18 by 9 inches and cut a semicircle on one side having a radius of 6 inches. Fasten three of these blocks to each side of the bin so that they will extend 9 inches above the top of the bin. Take wire netting of the proper width with ½-inch mesh and 5 feet in length and fasten it to the concave part of the blocks. It will be necessary to cut the wire screen on one side so that the door may be opened.

3. A standpipe 10 inches in diameter and 10 feet high was set up near the bin, its mouth on the same level as the top of the bin, so that a 60-inch square and a 10-inch circle were put in competition as practical snow catchers, thus indirectly bringing out the effect of stream lines at large and small apertures. The result was a systematic under-catch in the standpipe to the amount of 20 to 50 per cent. We sent out broadcast requests for suggestions as to the best form of apparatus for a seasonal snow gage, and from about 30 replies it seemed that the usual form of apparatus suggested depended upon a pipe of some kind moved to face the wind in various positions. It was found that these small pipes often fill up at the mouth in moist snows and become unserviceable. In general it was necessary to show that no snow gage depending upon a small pipe could be regarded as a candidate for the position as the basis for future developments in constructiong a seasonal snow gage.

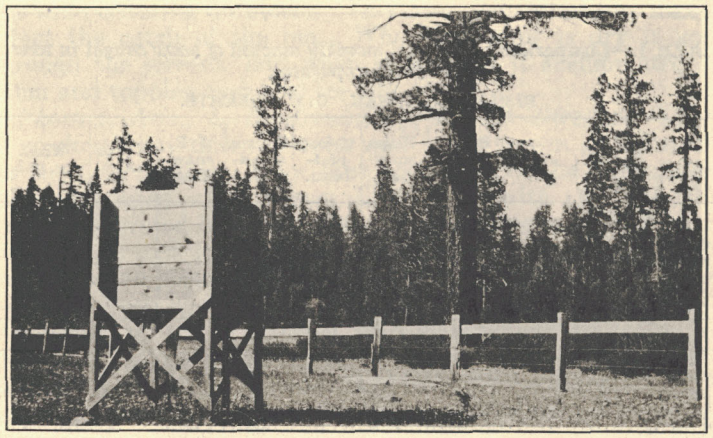

FIG. 4.—Weather Bureau snow bin near Tahoe City, Lake Tahoe, California, 1909.

4. The regular Weather Bureau rain and snow gage was set up for use in time of rain and for comparison. It has the defects of the 10-inch standpipe, and is not reliable.

5. The vertical scale, consisting of a board painted in feet and tenths, was set up to show the depth of snow remaining on the ground at a given place. This is not in any way connected with the snow bin as a seasonal gage, but it is intended to set up numerous vertical scales, which can be visited occasionally, or read at some distance by means of an opera glass, so that from such reports an idea can be gained of the state of the snow in the forests, ravines, and canyons.

6. Prof. J. E. Church, jr., who established the Mount Rose Mountain Observatory near Reno, Nev., has invented a boring tube for measuring the depth and density of snow in a drift or in the open. It consists of a tube of steel with a cutting edge of special form, which will penetrate about 6 feet of hard snow and bring up a core that can be weighed and converted into water equivalent for record. This device seems to work well and to serve a valuable purpose.

Table 1 collects together the total monthly amounts of snow caught at the various stations by means of the several pieces of apparatus, as given in the monthly reports from the observers at the comparative stations equipped for this purpose. The columns give in succession the amount caught in, (1) the louvered bin, (2) the plain bin, (3) the 10-foot platform, (4) the 10-inch standpipe, (5) the Weather Bureau snow and rain gage. The number of snows and the general kind of the wind at the station during the month are recorded in columns 7 and 8. The stations are located in various types of places, in the level open country, in forests, in bleak wind-swept places, and in protected canyons.

An inspection of Table 1, which gives the snowfall totals by months, leads to the following conclusions, which are strengthened by an examination of the individual snowstorms not here published as given in the reports.

(1) The platform is subject to drifting in high winds so as to be unserviceable.

(2) The 10-inch standpipe is liable to a deficiency in catch to the amount of 20 to 50 per cent.

(3) The plain snow bin catches a normal amount of snow, but it is not evenly distributed on the floor.

(4) The bin with louvers on the inside catches a normal amount and distributes it evenly.

(5) The bin with louvers on the outside needs further experimental study to discover the best shape for the outside louvers.

(6) The vertical snow scale is useful in measuring the depth of snow on the ground at date.

(7) The Weather Bureau rain and snow gage should be placed within and near the center of each snow bin for measures of rain and wet snow.

TABLE 1.—*Comparison of the total monthly amount of snow caught in several pieces of apparatus.*

BISMARCK, N. DAK. O. W. ROBERTS.

Month.	Louver snow bin.	Plain snow bin.	10-foot platform.	10-inch standpipe.	W. B. snow gage.	No. of snows.	Wind. m. p. h.
1909–1910.							
October		1.7	1.5	0.9	1.6	3	9
November							10
December		14.8	14.5	5.8	15.5	19	12
January		6.6	6.5	2.9	6.6	9	7

LEAD, S. DAK. E. F. IRWIN.

October		1.0	1.0	1.0	1.0	2	strong.
November		7.7	6.5	7.0	7.5	7	moderate.
December		19.0	11.8	11.8	12.5	8	strong.
January		15.5	6.0	22.3	24.5	11	strong.
February		6.1	0.9	4.8	5.9	7	light.
March				11.0	10.0	3	light.

DRY GULCH, MONT. R. F. YOUNG.

November		3.3	3.7			1	3
December	5.5		5.8	4.0		2	light.
January	14.3		14.3	9.1		3	light.
February	27.2		24.9			2	light.

RED LODGE, MONT. I. A. DRAPER.

November	2.5	1.5	2.3	3.3		3	
December	19.9	11.9	26.5	10.8		6	high.
January	6.5	5.6	6.7	4.5		2	light.
February	8.1	5.2	4.7	4.7		3	high.
March	2.4	2.2	3.0	1.2		1	light.

SHEEP HILL, IDAHO. C. M. GARDNER.

November		10.7	12.0			2	
December	34.2	16.4	48.2			7	
January	38.5	36.5				7	
February	47.4		45.7			6	

MAMMOTH HOT SPRINGS, YELLOWSTONE PARK. ANNE ELLIOTT.

December		10.5	2.5			5	
January		15.0	15.0			5	
February		17.1				11	
March		6.0				3	

COCONINO (FLAGSTAFF), ARIZ. G. A. PEARSON.

December	27.4		26.5			7	5
January	11.3		20.6			3	4
February	5.6		27.5			2	9
March	14.9	15.0	22.3			3	

GRAND VIEW, ARIZ. P. O. BERRY.

December		37.5	19.8	28.4		8	
January		21.7	9.9		16.7	6	moderate.
February		10.3	4.6	8.0	7.7	2	moderate.
March		6.8	2.7	4.8	4.6	3	brisk.
April		1.7	0.7	0.2	1.3	2	brisk.

YAMPA, COLO. P. A. HUGHES.

November	17.7	18.2	9.3	12.2		7	
December	18.8	18.1	9.7	12.3		11	brisk.
January	8.6	10.3	21.0	6.1	6.6	7	high.
February	8.4	8.3	54.5	4.1		10	brisk.

STEAMBOAT SPRINGS, COLO. M. E. HOUSTON.

November		13.5		6.5	9.3	5	moderate.
December		29.7		24.9	28.1	9	light.
January		14.2		13.8	14.5	6	light.
February		29.3		22.0	34.8	6	brisk.

TABLE 1.—*Comparison of the total monthly amount of snow caught in several pieces of apparatus.*—Continued.

FAIRVIEW, COLO. ELIZABETH L. GRAY.

Month.	Louver snow bin.	Plain snow bin.	10-foot platform.	10-inch standpipe.	W. B. snow gage.	No. of snows.	Wind. m. p. h.
November		45.5	45.5	43.1	44.9	7	light.
December		66.7	65.9	61.6	64.1	6	light.
January		11.1	10.7	8.6	10.6	3	light.

STRAWBERRY VALLEY, UTAH. F. W. CATER.

November	36.5	36.0				10	
December	50.0	49.5				11	
January	30.0	29.5				10	
February	67.5	67.0				10	
March	13.0	13.0				6	

CARD CANYON, UTAH. L. E. HAMMOND.

December	15.9	12.2	16.6			6	
January	13.2	12.0	14.7			4	
February	16.0	14.9	17.4			5	

MOUNT ROSE RANCH, NEV. F. T. ELKINS.

November	14.6	15.0	13.8	8.5	14.0	2	4
December	25.3	25.6	24.7	13.6		7	7
January	25.9	26.2	27.9	16.8		5	10
February	5.9	5.9	5.9	3.3		4	9
March	8.9	8.9	9.2	6.1	8.5	3	6

TAHOE, LAKE TAHOE, CAL. R. WATSON.

November		26.0	26.3	24.0	24.0	3	
December		42.0	42.0	35.5		6	
January		71.5		80.0	76.0	6	
March		1.2		0.9	1.2	2	

GREENHORN, OREG. A. CHASE.

December	45.3		45.1	28.9	19.3	13	light.
January	61.9		61.1	31.7	50.9	20	light.
February	76.0				67.2	21	brisk.
February 1–14	7.6		7.2	1.8	6.3	6	light.
March	5.3		5.3	1.2	1.5	3	light.
April	7.2		7.2		0.2	6	light.

MEACHAM, OREG. F. E. DIVENS.

November		11.0	11.0	4.5		4	
December		29.5	28.7	14.8		5	high.
January	55.4		44.7	14.7	14.1	13	moderate.
February	80.9		80.6	77.0	81.2	11	light.
March	5.0		4.5	3.0	5.0	1	light.

LA PORTE, CAL. C. W. HENDEL.

November		32.0	32.2			7	light.
December		72.5	72.5			12	light.
January		99.5	96.3			13	moderate.
February		33.4	34.1			8	light.

BLUE CANYON, CAL. J. B. KNAPP.

January		83	114	39		8	

EXTRACTS FROM SPECIAL REPORTS.

The following brief extracts from reports by the section directors and observers, are nearly unanimous in support of the 7 conclusions given above, and, indeed, there has been no real difference of opinion expressed:

Bismarck, N. Dak., O. W. Roberts, Section Director.—The general conclusions reached as to the various methods of snow measurement are that, the snow bin is the best, the others ranking as follows, platform, regular snow gage, vertical scale, and standpipe. The results obtained from the use of the latter are such as to warrant the discontinuance of this system. I regret to state that the results from the vertical scale were not such as were expected. Whenever there was a discrepancy between readings of the snow bin, regular snow gage (station) and the snow platform, it was found that the largest amount was contained in the snow bin, and the least in the snow gage. Owing to the fact that the comparative apparatus was located in the midst of a dense wood, where there was seldom, if ever, any perceptible wind movement, the accumulated snow was

quite uniform both in the snow bin and on the platform. It is believed that had the snow bin been equipped with louvers the measurements at various parts of the snow bin would have been still more uniform. For conditions in this vicinity the louvered snow bin, vertical scale, and station snow gage are all that is required. Under certain conditions it is obviously necessary to equip the louvered snow bin with an attachment for storing the accumulated snow for a considerable time.

Huron, S. Dak., S. W. Glenn, Section Director.—In my judgment the bin louvered inside, the vertical scale, and the Weather Bureau gage, are the best for the purpose. The mountain snowfall observers have in some instances complained that a high wind will sometimes either blow part of the snowfall out of the plain bin or pile and compact it in the corners. Some of the snow that falls here, particularly in very cold weather, is feathery and light, and is easily affected by a wind of only moderate force. In this State the platform is practically worthless, and the standpipe does not appear to properly catch the snowfall.

Helena, Mont., R. F. Young, Section Director.—I have the honor to state that the work in this connection at this station confirm, in most part, the conclusions [summarized above (1) to (7)]. This is not entirely true, however, in the case of the platform and board scales. The platform at Dry Gulch station, near Helena, appeared to catch at least as nearly the normal fall of snow as the louvered box, and it was invariably more evenly distributed. In no case was there any noticeable drifting of the snow on or off the platform. The reason for these favorable results may doubtless be found in the fact that the platform was entirely surrounded by a fairly thick growth of small timber, which protected it from the effects of high winds. At the Red Lodge, Mont., station, which is wholly unprotected by timber, the platform was found to be unreliable in storms accompanied by high winds. There are some rather serious defects in the board scales as a means of obtaining the depth of snow on the ground They appear to serve fairly well where snow accumulates to a depth of several feet, but even here the depth, as a rule, can not be read from a distance with any degree of accuracy because of the depression that always exists around an object of this kind. For ascertaining the depth on the ground it is believed that, on the whole, better results could be obtained by the use of specially designed measuring rods (as Church's tubes) the measurements to be taken in permanently selected localities. These places might be marked with signs and numbers, in order that the depth from month to month, and from season to season, may be comparable.

Red Lodge, Mont., J. A. Draper, Observer.—The platform is a very inaccurate apparatus to take measurements from owing to the fact that when the snow is shoveled from it after each storm the wind drifts it full regardless of how heavy the snowfall actually is. Commenting on the screened bin I can only say that it has done remarkable service so far. I believe that this method of catching the snow comes nearer representing the true snowfall than any method yet inaugurated. The snow is generally level in the bin, and but very little clings to the slanting boards nailed on the inside. When the storm is accompanied by very high wind, however, there will be a little snow clinging to the louvered boards. The pipe has not, to my thinking, caught a very true proportion of the snow. It seems to catch the snow and hold it on the sides of the can at the top while at the bottom, or near the bottom of the pipe, it clings only to one side, depending, of course, on the force of the wind. Regarding the plain bin, I will say that if the wind is light, or none, the snowfall will be level in the box, but if it is accompanied by high wind the snow will drift in the bin.

Boise, Idaho, E. L. Wells, Section Director.—I have the honor to report that such experiments as have been made in this State lead to the conclusion that the louvered bin without screens gives the best results. In many sections the platform would probably do as well, as in the forested mountains regions the snow falls with very little wind and seldom drifts. This would not be true of the barren ridges. The 10-inch pipe has not given good results. The vertical scale is of value in giving the depths of snow on the ground, particularly in forested areas, where the snowfall is uniform. The observer from the Sheep Hill station reported that he failed to discover any evidence of eddies in the air currents in the louvered snow bin. In his opinion the louvers are a distinct advantage, the snow in the louverd bin being absolutely level, no matter which direction the wind is during the storm. He states that the screens do not affect the catch of the bin. When the snow is dry it goes through the screens, and when it is moist it accumulates on them and topples over into the bin.

Phoenix, Ariz., L. N. Jesunofsky, Section Director.—There is no doubt but that the outer and upper screen attachments on the 5-foot cubical snow bins do not serve the purpose for which intended. The observations made with the plain bin and the louvered bin show that a larger percentage of snow is collected in the louvered bin, and that the snow lies more evenly in the bottom of the louvered bin. The 10-foot standpipe has given no satisfactory results whatever. The snowfall is collected on the inner sides, scarcely reaching the bottom of the pipe. In melting the snowfall after it is caught in the standpipe, the water equivalent is found to be about 25 to 50 per cent less than the measurements made from the plain snowgage. With reference to the measurement of snowfall made from the 10-foot platform, it was found that, where from 5.0 to 15.0 inches of snow laid on the ground, in many cases the platform was bare on one side, with perhaps 2 to 5 inches of snowfall on the opposite side, and that the faster the wind blew the less snow settled upon the platform. It would seem that the best interests of the Mountain Snowfall Service require the use of the louvered snow bin, the snow scale, and the Weather Bureau rain gage, since they have given the best results obtainable under normal conditions. For converting the snow bin into a seasonal snow gage for storing snow in the form of water, in inaccessible mountain regions during the winter months, it appears that many difficulties will have to be overcome; first, the cost of installation; second, the manner of carrying the material to the more elevated points of observation. With regard to the best method of storing snow in the form of water, I would suggest that the capacity of the snow bins be increased to just double their present volume. The inner and lower portions should be lined with zinc or tin up to 5 feet, so that the water will not leak. This plan would work practically if oil and salt were mixed together in the bottom of the bin.

Coconino, Experiment Forest Station, Ariz., G. A. Pearson, Observer.—The snow seems to accumulate on the louver planes on the windward side of the bin, while on the leeward side it drops down. The result is that on the windward side the snow along the edge of the bin, immediately below the louver planes, is below the normal depth, while on the opposite side it is above normal depth. As shown by the diagram[1] the measurements near the center are fairly uniform, and the average of all the measurements for the bin gives a result very close to that obtained by taking the average of several measurements on the ground. I regard the platform as impracticable for two reasons: first, where there is any wind at all snow blows on to the platform from the surrounding areas so that it is necessary to clean it off each day; second, when the snow on the ground lies above the level of the platform fresh snow, if accompanied by any wind at all, will fill up the entire space above the platform, thus registering a depth equal to the total depth of both the fresh and the old snow on the surrounding areas.

Denver, Colo., F. H. Brandenburg, Section Director.—I have the honor to report that my experience justifies the following

[1] Diagram omitted.

conclusions: The platform is of value only in glades or other places protected from the winds. The standpipe is unreliable; it is apt to clog under certain conditions, and in others it fails to make the proper catch. The plain bin is fairly satisfactory in slight to moderate winds. In high winds measurements made 1 foot from each corner and in the center rarely show anything approaching uniformity. The louver bin has been found to be the most satisfactory device with which I am familiar. With tight sides so that high winds can not disturb the snow, the depths a foot from the corners and in the center have rarely shown serious disparities as regards depths. The outside curved louvers apparently add little or nothing to the value of the bin. *For ordinary mountain stations where daily observations are taken I think it advisable to keep the rain as well as the snow gage in the center of the bin with the top say 12 inches above the floor.* The alterations in the bins in use would be simply the cutting of a hole for the gage, the Weather Bureau crate being discarded. The support for the part of the gage projecting below the floor of the bin could be so arranged as to permit the removal of the gage without going into the bin. This would be of advantage when precipitation is in the form of rain.

Salt Lake City, Utah, A. H. Thiessen, Section Director.–Most of my observers agree that the louvered bin catches the snow best, but they complain of the inability of any bin retaining the snow which has melted, that is any bin now in use by this Bureau. The following description of a bin devised by Mr. Alter, is worthy of consideration: This bin consists of a vertical pipe or tank with corrugated sides, the corrugations running up and down, to prevent breaking during freezes. About 6 inches from the top is a shield or apron to counteract eddies. The apron does not join direct to the pipe, the opening allowing the snow accumulated on it to fall through to the ground. In operation the snow and precipitation in the form of water falls in the tank, and settles on a layer of oil heavier than water which covers the bottom to a depth of 6 inches. While this has never been practically tried it is supposed that this quantity of oil will prevent the tank from bursting where the bottom is fastened to sides, and that the corrugations will give enough to prevent the sides from breaking. Of course, a light oil should also be used to keep the liquid surface in the gage covered to prevent evaporation.

Mount Rose Ranch, Nev., F. T. Elkins, Observer.—The louver snow bin recorded a trifle less than the plain snow bin, probably on account of some of the snow being held on the angle boards. The 10-inch pipe was useless for recording snow. The first of the snow was very wet and adhered closely to the metal work, clogging the orifice of the 10-inch pipe and materially reducing its diameter. The concave wirework of the louver bin held no snow, but the snow piled on the convex network to the same depth as that contained in the bin. On the platform the drift was deeper and diametrically different, varying from 11 inches at the south end to 4 inches at the north end.

Reno, Nev., H. F. Alps, Section Director.—The measurement of snow in the stand pipes showed the depths to be much less than measurements taken in the other pieces, and this is due to the moist snow collecting at the top and decreasing the size of the opening. There was little difference in the readings of the plain snow bin and the louver bin fitted with wire screens. It seems that when the snow is moist, or the wind light, the snow adheres to the wire screens and closes the meshes. The observers generally agree that the snow bin affords the best means of measuring the daily snowfall. The snow bin, rain gage, and snow scales make a very good station equipment.

Greenhorn, Oreg., Alfred Chase, Observer.—I believe the snow bin is giving an accurate record of the snowfall, and raising or lowering the outside louvers would not better the apparatus. The 10-foot platform is now at the bottom of a 6-foot hole, and so catches much drift, several feet of snow sometimes blowing onto it. I have tried to eliminate drift from my measurements, and so when much snow has drifted I have put the snow bin measurement for the platform. The 10-foot pipe varies considerably, sometimes giving about as much as the snow gage, and at other times very much less. I do not consider either platform or 10-foot pipe of much practical use up here in in the deep snow country.

Blue Canyon, Cal., J. B. Knapp, Observer.—To my mind, the bin is the only reliable machine to measure snow in. The platform works as well as the bin when there is no wind, or as long as it is kept on the level with the snow, but when the old snow gets higher than the platform, the winds drifts the snow on it in a short time. The pipe I believe to be absolutely worthless. If the snow is a little damp it gathers around the aperture and in a short time closes it very nearly up. Even with a dry, light snow the pipe does not seem to catch it. This may be caused by the wind.

Sacramento, Cal., N. R. Taylor, Local Forecaster.—I quite agree with you (J. B. Knapp) as to the impracticability of the pipe and platform. I also, think that Professor McAdie shares our opinion.

San Francisco, Cal., Prof. A. G. McAdie.—In general my experience confirms the views of the Central Office with regard to the unreliability of the platform and the unlouvered snow bin.

FIG. 5.—Mountain Snowfall Observer at the Reserve scale station No. 69, Jackson County, Oreg.

THE SEASONAL SNOW TOWER AND THE RAIN GAGE.

It is necessary to infer from the preceding uniform testimony that it is not proper to give further consideration to any plan of constructing a seasonal snow or rain gage that depends upon a pipe having a small diameter, such as the usual Weather Bureau rain gage, the 10-inch standpipe, and the numerous automatic devices fitted with similar pipes for the catchment. On the other hand, it has been made plain that a large louvered bin affords such a control to the precipitation that a small pipe set near the bottom of the bin will receive a normal amount of snow and rainfall. *We infer that all the stations of the Weather Bureau should be equipped with snow bins, and that the rain gages should be placed inside, the open top being within a few inches of the floor of the bin.* This apparatus will tend to relieve the problem of catching precipitation in the cities, where the wind eddies are so troublesome around the bulidings.

Having arrived at a sound principal for catching the snow and rainfall, it is proper to make suggestions regarding a seasonal reservoir for conserving the precipitation, to be used in places difficult of access to regular observations. It seems to me that we can properly make some experiments along the following lines:

1. Convert the snow bin into a snow tower, 10 or 20 feet high as required, by boarding down on the frame to the ground. Insert a galvanized iron, or a copper, tank of of rather large sectional area, say 3 feet square; slope the bottom boards of the floor of the bin so that the snow or rain will readily slip down into the tank; fill the space between the tower and the tank with hay, leaves, sawdust, or earth for a protection against cold winds and moderate freezes; put in a piece of rubber tube about 3 inches in diameter, to relieve the pressure on the the tank if the ice forms, so as to stand vertically in the tank from the bottom to the top; a good supply of light oil should be placed in the tank to check the evaporation; it is probable that a supply of salt will be useful in turning the snow into water, if the rusting effects on the metal of the tank can be avoided; the arrangement of door, ladder, and conveniences can be left to experience.

2. It would be well to take up the problems regarding the further development of the snow towers, in connection with the forest experiment stations, where the presence of suitable observers in the field will insure proper suggestion and supervision. It is my belief that by a proper adjustment of the *outside* louvers, some further improvement can be made in separating the horizontal drift from the vertical component of the fall.

3. There will be considerable expense connected with the construction and the installation of snow towers in remote mountain places, but it is evident that the problems of irrigation and water power will soon justify very considerable expenditures of money in this direction.

The following remarks on the seasonal snow gage are extracted from the reports from the section directors:

Denver, Colo., F. H. Brandenburg, Section Director.—I inclose a sketch[1] of a form of seasonal snow gage that I think will give satisfactory results with the use of salt and oil. The outside is the snow bin in use, with the exception that the boards extend to the ground with a low door. The floor is omitted. In the center is placed a metal cylinder about 24 inches in diameter and 6½ feet tall, the bottom resting near the ground. A faucet at the bottom similar to that on the tipping bucket gage will permit emptying the gage. About 4 feet above the bottom a tight-fitting door should be provided to permit inspection of the inside of the receptacle. This form of gage obviates the necessity of making an excavation to prevent freezing, as the snow that falls alongside the gage would afford as satisfactory protection from the cold as an excavation unless this were made very deep.

Portland, Oreg., E. A. Beals, District Forecaster.—After a careful study of the letters received from the snowfall observers in this State, I have concluded that the louvered bin, with sloping or hopper bottom opening into a metal or cement storage reservoir, is the only practical plan so far suggested; the use of salt and oil in the reservoir would avoid freezing and evaporation. The construction of the storage reservoir could be varied to suit the location of the bin. On some of the small benches in the mountains, the container could be sunk in the ground, but on the rocky slopes and summits this would be impossible unless blasting were resorted to. The construction and maintenance of these bins would undoubtedly be expensive. Among other plans suggested is that of a louvered bin with a depth of 10 feet or more; the bottom to be lined or made water tight to a height of 5 feet, and the winter snowfall to be allowed to accumulate in this bottom. Freezing and evaporation could be avoided by the use of salt and oil.

San Francisco, Cal., Prof. A. G. McAdie.—My opinions regarding the proper method of measuring snow are as follows:

1. Depth of snow is of less importance than the density of the snow.

2. As far as possible we should record the water equivalent. At low levels this is best done by a weighing snow gage, something similar to Fergusson's automatic snow gage.

3. At elevations above 5,000 feet, and at inaccessible places, some gage of tank form will be necessary.

4. Prof. J. E. Church, jr., of the University of Nevada, Reno, has a form of gage which may be serviceable in sampling snow density during one or more day's travel.

5. Regarding the type of seasonal snow gage designed by the writer, I have received under date of March 27, a letter from Professor Church, in which the following occurs:

> The water in your tank at the ranch did not freeze a single time during the winter. If we can increase the diameter of the intake pipe to 18 inches without permitting undue evaporation from the tank, we can probably catch sufficient of the entire evaporation to indicate the essential fall of the snow. The narrow intake pipe is too small for winds, though satisfactory where calms exist.

I think Professor Church's suggestion a good one, either to increase the diameter of the intake pipe, or to combine some form of bin, properly louvered, with the tank arrangement below. There is, therefore, a general opinion that the louvered snow bin can advantageously be converted into snow towers for conserving a season's snow.

Judging from all these reports it would seem to be good policy to take the two following steps:

1. Introduce the snow bin at all Weather Bureau stations in the United States for the catchment of snow and rain.

2. Continue experiments with the snow bin towers in order to arrive at the best form of the apparatus for conserving a seasonal snowfall in places where no observers reside, but which can be visited twice each year, first in the autumn when snows begin to fall, and second in the spring just before melting takes place.

Without taking up further the developments of the snowfall in connection with the topography of a region, there are certain ideas which make it probable that the relations between snowfall and accumulations in the gulches and ravines can be worked out, if the necessary observations with snow towers can be secured.

[1] Omitted.

THE TEMPERATURE CONDITIONS OF BOSTON, MASS.[1]

By ANDREW H. PALMER, A.M. Dated Cambridge, Mass., Apr. 28, 1910.

INTRODUCTION.

The following is an abstract of a quantitative study of the temperature conditions of Boston, Mass., based upon observations made by means of standard instruments for a period of 38 years. Little attempt is here made to explain the causes of the results obtained. During the period under consideration the exposure of the thermometer was changed twice, the present exposure being that inside the standard instrument shelter of the United States Weather Bureau located on the roof of the Boston Post-Office Building. Its height is 115 feet above the street level and 125 feet above the level of the sea. In regard to the changes in the position of the instruments, it should be stated that neither of the two changes was great enough to affect the results in any marked degree, as the three locations are less than 200 feet apart horizontally and not more than 25 feet vertically. Although there was undoubtedly some slight effect caused by these changes in exposure, it was so slight that no correction was applied by the Weather Bureau, and none has been applied in the present study. It should also be stated that all of the temperature readings are given in degrees Fahrenheit.

[1] A study of the temperatures of Boston, based upon the observations made by the United States Signal Service and the United States Weather Bureau during the period January 1, 1871–January 1, 1909, consisting of a brief summary of a thesis prepared under the direction of Prof. R. DeC. Ward in an advanced course in climatology, Geology 20e, at Harvard University, between February and June, 1909.